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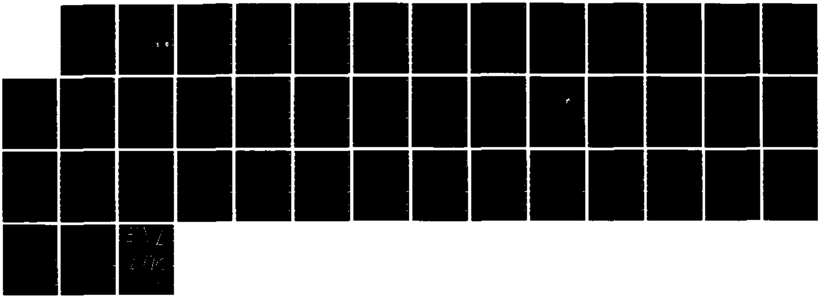

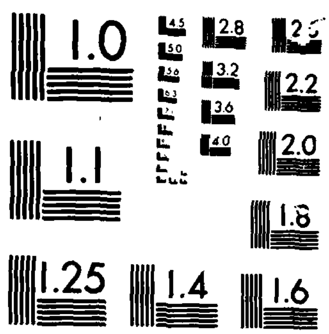

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AD-A167 991

AWS/TN-79/002

WEATHER SERVICE

FORECAST REVIEWS AND CASE STUDIES

Kenneth E. German, Col, USAF

May 1979

Approved For Public Release; Distribution Unlimited

AIR WEATHER SERVICE (MAC)
Scott AFB, Illinois 62225

REVIEW AND APPROVAL STATEMENT

This publication approved for public release. There is no objection to unlimited distribution of this document to the public at large, or by the Defense Documentation Center (DDC) to the National Technical Information Service (NTIS).

This technical publication has been reviewed and is approved for publication.

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One of the most effective ways of improving forecasting performance is the forecast review (sometimes called bust review). The forecast review improves the effectiveness of the forecaster who does the review and it is helpful to others who forecast for the station. Even though the benefits are nearly universally acclaimed, staff visits often find that the forecast review programs fall far short of this ideal. One of the reasons often given is that there is inadequate guidance available concerning the content of a good forecast review and how to judge its effectiveness. This technical note is written to help meet this need.

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May 1979

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DISTRIBUTION

Wings, squadrons, and detachments (except SESS and STAFFMET units).
3350 TTCHG Chanute AFB IL 61868
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May 1979

PREFACE

One of the most effective ways of improving forecasting performance is the forecast review (sometimes called bust review). The forecast review improves the effectiveness of the forecaster who does the review and it is helpful to others who forecast for the station. Even though the benefits are nearly universally acclaimed, staff visitors often find that the forecast review programs fall far short of this ideal. One of the reasons often given is that there is inadequate guidance available concerning the content of a good forecast review and how to judge its effectiveness. This technical note is written to help meet this need.

TABLE OF CONTENTS

Chapter 1

INTRODUCTION

The purpose of a forecast review is to improve forecasting. Generally, this purpose is achieved if a forecaster carefully reanalyzes data for a given situation so that he and others better understand what happened. A forecast review should be initiated whenever the forecaster does not thoroughly understand the sequence of events. Station workload usually makes such an idealistic approach impractical; so reviews usually are done for those events most likely to increase forecasting capability. The beginning forecaster should seek advice from more experienced forecasters concerning causes of events and selection of events to review. This chapter will provide a few definitions and discuss unit forecast review program procedures.

1.1. Definitions.

Definitions of terms such as bust review, bust analysis, forecast review, and case study have been attempted by many without achieving universal clarity or acceptance. On the basis of these experiences, it appears that a continuum exists and precise definitions are neither possible nor required. The definitions that will be used in this publication will be arbitrary, primarily relying on the amount of time required to do the job. We begin with two terms associated with unit daily quality control activities so that the forecast review is easier to define.

1.1.1. Bust Analysis. Whenever a forecast is no longer representative, it must be amended. In this process, normal procedures require a reason be given for the amendment. The activities involved in reassessing the situation before writing the amendment comprise a bust analysis. There usually is little time for this function; so the bust analyses tend to be short. Some possible examples are given below:

The front was delayed by development of a wave.

The front accelerated.

A warm front intensified.

The stratus occurred early.

Precipitation began six hours early.

A squall line developed unexpectedly ahead of the front.

Thunderstorm dissipated.

These examples really do not say much, but they are better than a statement that the forecast was amended because ceiling was out of category. Of course, additional information can be written if desired. Every amended forecast provides an opportunity to improve forecasting capability, and each forecaster should do as much investigation as workload permits.

1.1.2. Forecast Evaluation. One of the daily duties of the station chief should be to review the forecasts issued. Part of this task is to evaluate the forecasts, the bust analyses, look for trends, and determine what actions (e.g., forecast review, case study, nothing) are required. This process is called forecast evaluation.

1.1.3. Forecast Review. A forecast review (sometimes called bust review or a forecast reanalysis) is an after-the-fact review of the observations, analyses, and forecast aids which were available to the forecaster to determine whether existing station procedures were adequate, and to identify the ways to prepare a correct forecast. The time required for this process normally should be less than one hour. Chapter 5 contains examples of forecast reviews prepared by AWS units. We have typed the comments, but in actual practice the forecast reviews often are handwritten.

1.1.4. Case Study. A case study is sometimes called an in-depth reanalysis. The basic purpose of it is the same as the forecast review, but usually considerable effort is used to collect and present the data and analyses thoroughly in a clear and readable form. The effort usually requires several hours' concentrated work and some rewrites over a period of several weeks or months. Chapter 6 contains examples of case studies.

1.2. Procedures.

A systematic, effective, forecast review program provides tremendous potential for improved forecasting. To realize this potential, procedures have to be established and made to work. Each unit has unique needs, so the program has to be written accordingly, that is, by each unit. These programs should consist of the elements described in the following paragraphs.

1.2.1. Selecting Thresholds. In general, workload places practical limitations on the amount of effort that can be applied to a forecast review program. A program that is too stringent or is ill-conceived generally becomes perceived as non-productive or punitive work. Therefore, careful planning is required when establishing the program, and periodic reassessment of the program is required to make sure it continues to work effectively.

The station managers must ensure that the forecast review program is not interpreted as punishment. The sole intent must be to improve individual and station performance; the forecast review simply is one of the most effective ways. Forecasters who willingly do forecast reviews should be praised for their professional attitude toward their unit and for their leadership and initiative. Noteworthy reviews should always receive public praise. A forecaster who knows that extra effort will be recognized is more likely to produce.

Some events are so important to the station operation that they should be given special consideration for a forecast review. Examples used by various units are:

An unforecast event had significant adverse customer impact.

Weather warning criteria met but no warning issued.

Weather warning issued but event does not occur.

Weather conditions below 1000/2 occur without being forecast or are forecast and fail to occur.

Selected events.

The particular thresholds chosen should be designed to lead toward improvement of specifically identified aspects of a station's operation. These goals should be clearly stated and explained to all forecaster personnel. In most cases, then, the duty forecaster should initiate the required review. Only in a few exceptional cases should it be necessary for a station supervisor to direct forecast reviews. Obviously, when such direction is needed, it should be done without hesitation.

Thresholds that are beyond the state-of-the-art normally should not be established. If a customer requires such accuracies, the Staff Weather Officer (SWO) is obligated to advise what the capabilities are, what improvements are possible and are being worked, and what is impossible. In AWS units, the difficult problems have been tried by many, and it is unlikely that these problems will be solved by inexperienced forecasters.

Sometimes an outstanding forecast merits a forecast review to document how a specific situation can and should be handled. An excellent example is at Chapter 5, Example 8. In this case the forecaster used local rules of thumb and thorough metwatch of upstream stations to produce an absolutely superb wind warning.

The station chief or DetCo should always be prepared to require a few forecast reviews to help improve unit or individual deficiencies identified through on-the-spot OJT or the verification program. In addition, a forecast review can be a good vehicle for providing training for the less experienced forecasters.

Occasionally an event will be so interesting or illustrative of typical weather at a location that a case study is desirable. A case study really is an expanded forecast review that contains copies of the basic facsimile or operational analyses, supplemental reanalyses, data and other charts that could be helpful in subsequent reviews. Although forecasters may initiate case studies, the station manager should assign several every year.

The first step in establishing effective forecast review procedures is to write down specific unit goals (e.g., improve wind warning performance by 20 percent, improve visibility forecasting by 10 percent) for the forecast review program. These may be different for each unit. Once the goals are established, then it is possible to write specific thresholds to assist the forecasters in selecting the cases or events for which forecast reviews would be most productive. Completion of this step enables the station manager to take the next logical step.

1.2.2. Operational Procedures/Instructions (OI). An OI should be written to specify the purpose or goals, the thresholds, and the procedures to be followed. The goals and thresholds have been discussed. The procedures to be followed can be specified in the OI or described on a forecast review form (see examples 1 and 2). These procedures normally will include:

Review of forecast aids used in making the forecast to determine if all pertinent available information was used, and if it was used properly;

Verification of the forecast aids to determine whether the guidance was adequate, incorrect or misleading;

Reanalysis to determine what actually happened. This step may require iteration with the previous step;

Identification of potential forecast hints and any other lessons learned;

Instructions for format such as local or standard form, letter or memo (See examples at Chapter 5, Examples 2, 3, 4 and 5, respectively); and

Review by station managers, feedback to forecasters, filing, and a system for periodic (seasonal) review.

When writing operational instructions, care must be taken to avoid unnecessary or fruitless activity. The best way to do this is to make sure forecasters understand the purpose of the program and then to give them the authority and responsibility to make it work. Forecasts that indicate correct trends but miss the timing by a few minutes or the ceiling or visibility by small amounts, normally do not require reviews. These subjective determinations can be made quite well by a duty forecaster who has been trained to know the customers' requirements and sensitivities. The review is discussed in Chapter 2.

Chapter 2

THE REVIEW

There are several ways of doing forecast reviews; differences are in techniques and length of investigation. The purpose of the review will largely dictate the approach used. For example, a review of severe convective activity would require a different approach than a review of a radiation fog episode. The forecaster's basic meteorological training provides sufficient background in most instances for selection of a suitable approach. The details of approach are variable. It's the results that count. Different forecasters get there in different ways, but generally all reviews should include the following:

2.1. Synoptic Description. This should briefly describe the synoptic situation prior to the valid time of the forecast. Key charts should be attached and referenced in this portion of the review. The written description should complement the charts. It is not necessary to describe the location of each feature, when it can be readily seen on a map. For example:

"A high pressure area with center located over southeast Indiana was dominating the Scott AFB area." This sentence, alone, is an adequate description. "A cold front extended from eastern Montana to central Nevada. Weak southerly flow existed throughout the Mississippi Valley." The last two sentences are not necessary because they contain information readily apparent from the attached maps and are not relevant to the fog forecast.

The purpose of the description is to provide an introduction and rough guide to synoptic classification. Most forecasters need or at least expect information on whether the synoptic situation is frontal or air mass and what type. Such comments provide a frame of reference which makes it easier for weather personnel to understand the subsequent comments and discussion.

2.2. Reasoning Used. This should provide a summary of the reasoning used when the forecast was prepared. Be sure to briefly mention key forecast guidance used. Examples include:

LFM indicated strong PVA in next 12 hours;

NWS discussion indicated low would move east; and,

PDUS indicated front would slow down.

In each case the referenced product should be attached to the review.

This step is important because it can indicate better ways to do the job as well as define any misinterpretations of existing guidance. Care must be taken to preclude ridicule or other adverse feedback to the forecaster. It is essential that this step be done frankly so that any problems can be solved. Irrational or emotional reaction by supervisors to these comments will quickly prevent any useful information from being obtained. In some cases, this information might have to be treated as privileged.

This mentally retained information is perishable and must be written as soon as possible after the event occurs. Whether the event was correctly or incorrectly forecast, it is this step that illuminates the effectiveness and understanding of the existing procedures.

2.3. Verification. In general, a summary of the forecast and the verifying observations or charts is required. The summary quickly describes the element forecast and whether it verified or not. Copies of the actual forecast and verifying observations should always be attached for subsequent reference. In cases where the subject is timing of a synoptic control, such as a front (wind shift) or a trough aloft (cessation of precipitation), charts showing the extrapolated (forecast) positions of the feature(s) and the verifying analyses (adjusted if necessary) should be attached.

2.4. Results. This discussion contains the results of the post-analysis, with emphasis on why the weather occurred as it did, and the factors responsible for the forecast's success or failure. This step is one in which payoff often occurs.

It will not always be possible to identify the real causes or to specify foolproof ways to prevent recurrence. Nevertheless, a painstaking effort is required. The appropriate charts should be examined closely, and whenever continuity or structure is suspect, other analysis solutions should be considered. In addition, the physical mechanisms causing the event are not always easy to identify. For example, advection fog might be identified as radiation fog and strong gusty winds associated with a strong surface pressure gradient could be attributed to local effect(s). When the causes of the weather that occurred are imperfectly known, the purpose of the forecast review is to help build a data base (several different descriptions of a similar event) that can be used to improve knowledge and understanding of the event.

2.5. Lessons Learned. No review is complete without a summary of lessons learned, as well as suggestions which would aid forecasters in the future under similar conditions. These are the conclusions and recommendations resulting from the work. As such, they deserve careful consideration and should be proposed with that expectation. The station supervisor should carefully evaluate each conclusion and recommendation.

In all the above steps, include pertinent information from other forecast reviews done for similar events and situations. Frequently, the observation or expression of another person assists in providing greater understanding of the physical processes involved in the event. Using the forecast review is described in Chapter 3.

Chapter 3

AFTER THE REVIEW

The act of completing a forecast review is only one step toward improvement of individual and station performance. The completed forecast review must be evaluated to ensure the work has been done carefully and completely, and that the conclusions and recommendations follow logically from the information presented in the written review. Some possible subsequent actions to consider include change in station procedure, further evaluation, refer to parent unit, and discussion with customer on capabilities. The following paragraphs explore these possible actions.

3.1. Technical Evaluation. Ideally the unit commander should perform this function, but in actual practice it usually will be done by the unit's technical leader (station chief, forecaster with most experience, etc.). One question might be "What constitutes technical adequacy?" There is no simple answer to this question; however, one criterion might be whether the evaluator personally could have used the suggested approach to arrive at a correct forecast.

Forecast reviews can be long or short, very detailed or not so detailed. The goal of the review, regardless of how long or detailed, should be to help the writer and reader identify those parameters that were and were not accounted for in the forecast. If the review does this, then it is of sufficient length and detail.

A few thoughts illustrating common technical weaknesses, written by 2WW/DNs on some forecast reviews are given below.

"A forecast review was accomplished because the ceiling and visibility did not improve as expected. The discussion was fairly complete, including forecast reasoning. The forecast was based on an expected trough passage from the south with subsequent instability improving visibility. Ceiling and visibility did improve briefly, but deteriorated again after trough passage. The problem was that advection from the south doesn't necessarily mean decreased stability. Low level inversions can become stronger rather than weaker, causing low visibility conditions to continue or to become worse. The person accomplishing the review aimed most of his criticism for the bust at the trajectory bulletin. Some important details were left out of the review. A trough was forecast to pass the station, yet there was no mention of continuity, and no indication of any attempt to use the latest surface synoptic information to note changing ceiling and visibility conditions just before and after trough passage at upstream stations. No mention was made as to what other information, besides the trajectory bulletin, might have been looked at to catch the fact that weak ridging and warming occurred behind the trough.

"Another review looked at a situation where visibility failed to improve as forecast. Fog dissipation was forecast to coincide with the breaking of a low level inversion due to surface heating. The forecast breaking temperature was hit on the nose, but occurred later than expected. The review was well done. One thing that might have been included was how well the Conditional Climatology Tables and Surface Heating Curves performed.

"A third review discussed a missed forecast where low ceiling, low visibility and rain caused by overrunning from the south was expected to continue, but, instead, conditions improved. The forecast was based on a low pressure center remaining stationary west of the station and maintaining overrunning conditions. Instead, the low moved east of the station and conditions improved significantly. Some important areas were not discussed. There was no mention of surface or upper air continuity or changes, such as the movement, deepening or filling of the low center. One set of conditions might cause the low to remain west of the station, while another might cause the low to move east rapidly."

Finally, Example 10 (Chapter 5) illustrates a good forecast evaluation. We collected many samples of forecast reviews, but few showed such constructive comments.

3.2. Commander's Evaluation. The unit commander must personally evaluate the review. In a large measure, the success of a forecast review program depends on the interest shown by the unit commander in the forecast reviews. The unit commander should make public comments about the positive points or characteristics of each review. For credibility, it must be clear that the unit commander has indeed read the review.

3.3. Use of Forecast Reviews. One possible outcome of the review is identification of any errors of omission or commission made in the stress of real time. This information can be used by the individual, but also can indicate a need for changes in station procedures, e.g., relieving the forecaster for a few minutes before TAF time, or arranging to have local flying weather information posted in squadron operations to reduce the number of phone calls. When the problem is readily defined, corrective action can be taken immediately. Subsequently, the review should be used for seasonal or orientation reading.

In many cases a single forecast review is not sufficient to identify effective, lasting solutions. These insufficiencies will be minimized if the review makes full use of all resources available. In-station resources include other shift forecasters, the station chief, wing weather officers, and the DetCo. Out-of-station assistance may be available from a nearby National Weather Service (NWS) or commercial weather service office. In addition, the parent unit technical consultant is available. Asking for assistance has the added benefit of ensuring that the parent unit is aware of unit problems and efforts to find solutions. With this knowledge, the technical consultant may be able to provide beneficial crossfeed from other units.

A unit might not want to do this much with a single forecast review, but, at the very least, the review should be held for consolidation with other forecast reviews of similar events. A collection of reviews provides deeper insights into forecasting than does a single review.

In those few cases when several forecast reviews fail to bring out practical solutions, the problem should be identified as a unit limitation, and forwarded through channels for long term solution. Some problems are beyond the state-of-the-art and should be labeled as such so that a research requirement can be written. In the interim, the unit should brief customers of the limitation, but strive to perform as well as possible.

The finished review should then be circulated among all forecasters, and any significant findings discussed at the next forecasters' meeting. Completed reviews should be filed by type and season. Part of the preparation for approaching seasons should include review of the appropriate forecast reviews by each unit forecaster. Because of the limited time usually available for such activity, it is important that each review retained for this purpose is easy to read, complete, and minimally redundant to other reviews in the collection.

Following each season, forecast reviews should be reexamined and common elements summarized by type. After several seasons, solutions to forecast problems often become evident; therefore, end-of-season reviews should be maintained for at least five years. Forecast reviews which no longer contribute to better understanding of the forecast problem may be discarded. Solutions to forecast problems should be included in the unit TFRN. Case studies are described in Chapter 4.

Chapter 4

THE CASE STUDY

As explained in Chapter 1, there is no way to clearly separate forecast reviews and case studies. Administratively, it is convenient to call those efforts requiring more than a few hours a case study. Forecasters who do case studies should be encouraged to publish their efforts in an AWS technical publication, or in one of the professional journals whenever others would benefit.

4.1. Rationale for Doing Case Studies. In meteorology, the case study is a basic building block in advancing the state-of-the-art. Often the road to progress has been smoothed through carefully done case studies. These studies provide the empirical evidence (observations) from which forecast hints and rules (theory) are devised. An example is the development of tornado and severe thunderstorm forecasting rules in AWS TR 200 (Rev). Another example is forecasting heavy snowfall as described in 3WW TN 76-2. These advances of science were made by doing case study after case study, until important relationships and parameters became evident. Other branches of science use a similar approach--make patient observations to establish a behavior and fit a theory to it. Only rarely has the advance been achieved in reverse order. It is difficult to overemphasize the importance and usefulness of the case study as a way to improve forecasting performance and increase understanding of meteorological processes.

The case study is used in the same way as the forecast review to work toward solution of forecast problems. The first few case studies of a phenomenon document typical situations in which the event occurred. Forecasters should review these during initial and subsequent seasonal orientations so that they are aware of the kinds of situations in which the event can occur.

When doing a case study, the first step is a reanalysis to determine how the phenomenon was produced and the specific sequence of events leading to it. Previous case studies and forecast reviews of similar events should be reviewed. It is during this careful review of past events, and comparison of one with another, that forecasting relationships and parameters often become evident.

The forecaster should not be discouraged by lack of progress after a few tries. The keys are patience and persistence. These are essential for success and nearly always reward the investigator who uses them faithfully.

The format of an effective case study can vary considerably as is illustrated by the examples mentioned below and in Chapter 6. However, at a single station, a standard format makes comparison of one case study to another much more efficient and effective.

4.2. Examples of Published Case Studies.

3WW TN 77-2, Case Study: A Report on the Storm System of 2 March 1977. Example of a study of a synoptic scale system which developed rapidly over the midwest CONUS.

AWS TR 200 (Rev), Notes on Analysis and Severe Storm Forecasting Procedures of the Air Force Global Weather Central. Case studies of several severe weather outbreaks are summarized in Appendices B, C, D, E, and F. These illustrate thorough analysis and description of the relationships of all levels and types of data.

2WW TN 78-5, Selected Case Studies and Synoptic Patterns Bring Significant Weather to Europe. Contains several studies of synoptic scale patterns.

USAFETAC TN 73-2, The Ocheltree Tornado, (a case study), 1 May 1972. An excellent study of a meso-scale development in Kansas and Missouri. Good use of radar photographs.

Other examples may be found in the various wing publications and in the professional journals. These studies required a lot of extra work to make them suitable for publishing. This extra work is not required for locally produced case studies, as is illustrated by the case studies in Chapter 6.

Chapter 5

EXAMPLES OF FORECAST REVIEWS

The forecast reviews in this chapter were selected from those submitted by the wings. The examples show several different approaches to doing forecast reviews. They are printed here as examples to illustrate portions of the discussions in the first three chapters. In addition, a forecaster may want to refer to them when ideas are needed about format or content. Each unit, of course, should have a number of forecast review samples on hand.

The reviews printed here have been modified to enhance their usefulness for this document. At the same time, we retained as much of the original review as possible.

5.1. Example 1, Forecast Review Worksheet.

This forecast review illustrates a review worksheet used at Det 3, 3WS 5WW at Myrtle Beach AFB, South Carolina. The cause of the improvement was identified and supported with copies of portions of the surface, 850mb, 700mb, and 500mb charts. (Charts in this example not included).

SUBJECT: Forecast Review DATE: 9 Nov 78

1. A bust review is required for the 07/13 Z forecast. The reason is two category bust. Complete the following and return to the chief forecaster NLT 5 working days from the above date. Attach any pertinent maps, forms, or data sheets that are applicable to your discussion. Remember, a Bust Review is a learning experience and is used to compile a Bust Review File.

2. FORECAST CONDITION: 8 BKN 25 OVC

3. OBSERVED CONDITION: 40 BKN

4. SYNOPTIC SITUATION: High over West Virginia with low offshore. Cold front had passed to southeast during the previous 36 hours. 850mb low in southern Georgia.

5. PREANALYSIS: What parameters were used to forecast the event and what did they indicate? Isotherm trough at 850mb at 09/00Z was well to the west, indicating that clearing trend would not occur.

6. POSTANALYSIS: What parameters were evident on the postanalysis that weren't evident before and what was their effect? Minor ridge west of Myrtle Beach at 850mb moved through Myrtle Beach giving a clearing trend. The 8 BKN first went scattered and then cleared out by 16Z. The 700mb at 09/00Z showed that the Georgia low was shallow and that Myrtle Beach was more under the influence of the minor ridge than seemed from the 850. The 500mb at 09/12Z showed the entire area under that ridge (chart not available at forecast time). We were basically under a ridge and the low ceilings were caused by onshore flow. As the high moved to the northeast, the flow weakened, clearing out the low ceiling.

7. SUMMARY OR CONCLUSION:

1. Watch for lows at 850mb that might have a ridge just ahead of them. The ridge in this case proved to be more important, as it was reflected aloft.

2. Although, there was no discernible trend, the condition has been present for 12 hours already, and should not have been expected to continue for another 3 hours.

5.2. Example 2. Another Forecast Review Worksheet.

This forecast worksheet is used by Det 17, 30WS, 1 WW at Yokota AB, Japan. Commendable features include: thorough instructions, space for analyses, ample space for discussion and station chief evaluation. Such a unit form has a number of advantages; additional data, charts, and maps can be attached, when needed.

FORECAST REANALYSIS WORKSHEET

DATE	6 Feb 78	FORECASTER		DUE DATE	21 Feb 78

REANALYSIS REQUIREMENT

TYPE OF FCST	FCST DTG OR NO	REASON FOR REANALYSIS
W W	02-01	No lead time surface winds >35kts

REASON FOR BUSTED FORECAST

CIRCLE ONE: UNFCST EVENT NON-OCCURRENCE OF FCST EVENT MISSED TIMING
MISSED TREND MISSED TYPE MISSED INTENSITY OTHER (EXPLAIN):

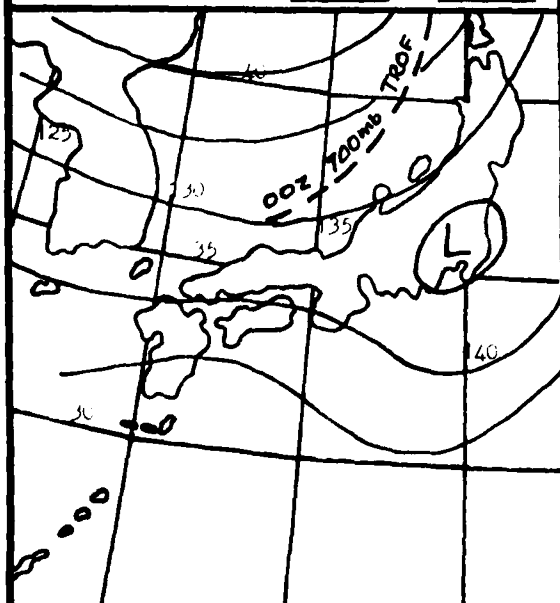
REANALYSIS STEPS

1. Review facsimile charts and locally prepared charts that were available prior to formulation of the busted forecast to re-evaluate synoptic conditions, occurring dynamic changes, and weather patterns. Depict the key analysis available that influenced your forecast below.

2. Review techniques/aids such as rules-of-thumb, forecast studies, movement/steering of systems, continuity of systems, observations, etc. used in conjunction with synoptic conditions to formulate the busted forecast.

3. Review facsimile charts, locally prepared charts, and other data available immediately following the time of the busted forecast to determine unanticipated changes in synoptic features, their dynamic causes, and resultant changes in weather conditions. Depict the first analysis available after the time of the bust below for the same level as the key influencing analysis.

PRE-FORECAST ANAL LVL SFC DTG 01/03Z



POST-BUST ANAL LVL SFC DTG 01/06Z

D17, 30WS FORM 0-5
JAN 78

REANALYSIS D... ... STEPS

1. Write a brief summary explaining the pre-forecast synoptic situation, techniques, aids such as rules-of-thumb, forecast studies, movement/steering of systems, continuity of systems, observations, etc. that influenced you to forecast what you did when you did.

2. Write a brief summary about post-forecast synoptic changes and how the changes produced the observed weather that caused the busted forecast at the time it did.

3. Write a brief summary about significant factors uncovered, and indicate additional analyses, changes in LAP procedures, techniques/aids, proposed rules-of-thumb, proposed forecast studies, or other information which might have precluded the bust and/or resulted in a better forecast and could aid forecasters in the future under similar circumstances.

REANALYSIS DISCUSSION

The local area was under the influence of a more intense than usual Kanto low. A cold trough was moving off the sea of Japan ahead of a 700mb trough. Snow showers were occurring along mountain ridges W-N of station. Prior to the 07Z forecast, pressure gradients between stations 47600-47548 (03Z) were only 4.2mb, RJNK-RJTJ 5.1mb and Mt. Fuji winds 240° @ 40 kts. This did not seem conducive to strong northerly surface winds especially that late in the day.

Unnoticed at TAF time was the fact that the pressure gradient 47600-47548 and RJNK-RJTJ (at 06Z) had both increased to 8.5mb. In addition, Mt. Fuji wind had veered to 260° @ 20 kts indicating approach of the 700mb trough. At 07Z the 700mb trough was nearly overhead as Mt. Fuji's winds had become 280° @ 34 kts. By 0800Z the cold surface trough began spilling over the mountains to the north. A line of snow showers developed northwest-northeast and began moving south on the crest of the cold air. Surface winds at RJTJ (10 nm NE) swung from 280° 14 kts to 320° 12/25 kts. Heavy blowing dust and a possible roll cloud from the rapidly moving snow showers to the north of the field was observed rapidly approaching. Station winds shifted to northerly at 0833Z reaching a peak of 41 kts at 0838Z.

The pressure gradient of 8.5 mb was not sufficient to cause 41 kts of surface wind, however, this plus convective down rush caused by the now dissipating snow showers was.

Recommend that regardless of time of day, in situations where a cold trough is approaching the station that the appropriate pressure gradients be closely monitored for strength and passage of 700mb trough be carefully progged for strong gust beginning time. The telltale line of convective showers should also be watched for.

(If additional space is required, continue on additional sheets of ...)

STATION CHIEF REVIEW

Excellent Bust Review with very valid recommendations! Comments?	DATE	21 Feb 78
	INITIALS	

5.3. Example 3. Forecast Reviews on a Forecast Worksheet.

We have schematically reproduced portions of a 2WW forecast worksheet form for two similar fog forecasts. Although these reviews are short, they were effective and useful. These reviews are from Det 36, 31WS, 2WW at Alconbury RAF Station, United Kingdom.

CASE I

TAF WORKSHEET

Prepared by: DATE/TIME: 14/0500Z

Forecast Reasoning: Dense shallow fog observed. Figure 5, Technique File indicates fog to break at sunrise plus two hours ... All indicators show break time 0830Z-0900Z, but sky above partial obscuration very clear (stars extremely brilliant). Therefore, moving break time to 0800Z.

TAF: 0514 VRB04 0200 42FG 2CI200 QNH 3010INS
GRADU 0708 VRB05 1800 42FG 2CI200 QNH 3011INS

Amendments: Time issued 0754Z Time required 0800 Z

Forecast Review: not required___ required X complete NLT 20 Oct 77

Objective indicators all pointed to fog clearance between 0830Z and 0930Z. Radiation foggraphs (Fig 5 Tech Development File) said 0830Z, 0930Z modified by notes. Fog clearance temperature from sounding was 10°C, heating curves showed 10°C 0830Z to 0900Z. All were considered in the forecast reasoning but TAF was constructed on one subjective input, very clear sky, indicating probable strong insolation and earlier break time/temperature. PP showed no sig. change at 0800Z.

FCSTR Signature ________________ DETCO Signature ________________

2WW Form 15
Oct 76

CASE II

Forecast Review: not required X required___ complete NLT ________

Objective indicator pointed to fog lifting between 11-12Z. The radiation fog graphs said 1129Z and the heating curves pointed to clearance at 12-13°. The fog started to lift at 11Z when the temp hit 12°, and improved to >1 nm at 13Z when we hit 13°. It was an excellent forecast.

FCSTR Signature ________________ DETCO Signature ________________

5.4. Example 4. Building a Data Base.

This excellent review does not provide firm conclusions, but care was taken to document all items "... so that after reviewing subsequent reviews perhaps more specific conclusions can be drawn." The review was done by Det 9, 7WW at Scott AFB IL.

Operationally Significant Weather Review

RVR less than 16

1. On 18 Aug 73 Scott AFB observed weather conditions that greatly impacted 375th AAWG operations. Three C-9A aircraft were delayed between one to two hours due to the terminal being below takeoff minimum conditions between 1145Z to 1338Z.

2. Situation.

a. Surface analysis. A high pressure area was generally dominating Scott with the center located in southeast Indiana. A cold front extended from eastern Montana to central Nevada. During the period of fog occurrence, the temperature-dew point spread varied from two to three degrees. Pressure values were between 1018 to 1019mb's. Surface winds remained calm until 1700Z.

b. Upper air analysis. The gradient level winds (approximately 3000 ft) were generally (190/10 at 0600Z, 230/03 at 1200Z, and 100/05 at 1800Z) light and variable at the time of occurrence. The 850mb analysis showed a band of moisture through central Missouri and central Illinois.

3. There really were no forecast aids that could help in forecasting this situation on August 18. Reviewing the period 15 through 19 August, below landing minimums occurred on three of the mornings. Throughout this period the synoptic situation was unchanged. Closer investigation of the mesoscale and microscale situation revealed very little difference between mornings that remained above landing minimums and those mornings that below minimum conditions occurred. Minimum visibilities on the 16th and 17th ranged from 3/4 to 1 mile. Whereas on the 15th, 18th and 19th RVR was 10-.

Forecast Trajectory Temperatures and Dew Points at 2000 feet.

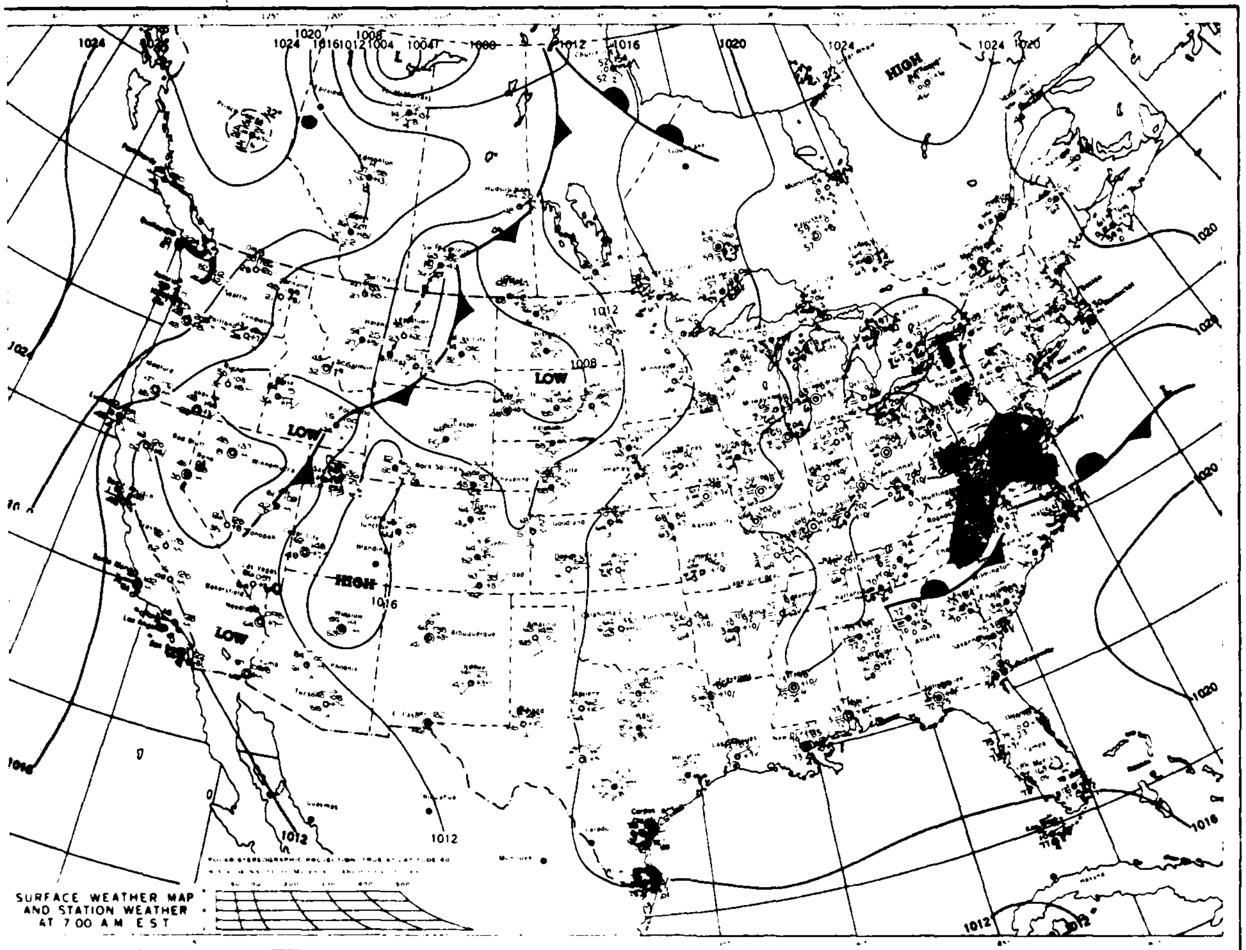
	15/00Z		16/00Z	17/00Z		18/00Z		19/00Z	
	T	Td		T	Td	T	Td	T	Td
12 hr	19°	14°	MSG	20°	19°	21°	18°	23°	19°
18 hr	25°	15°	MSG	19°	19°	21°	19°	25°	19°
24 hr	25°	18°	MSG	20°	19°	23°	19°	27°	19°

In conclusion, the following are results of this report: There were some other similarities between mornings that went below minimums. These similarities were 1) generally cloudy skies were observed during the previous day 2) clearing occurred at night 3) a rainshower occurred during the previous day and 4) the height of the inversion was 2000-3000 feet MSL. On the mornings that below minimum conditions did not occur one or more of these conditions were not met.

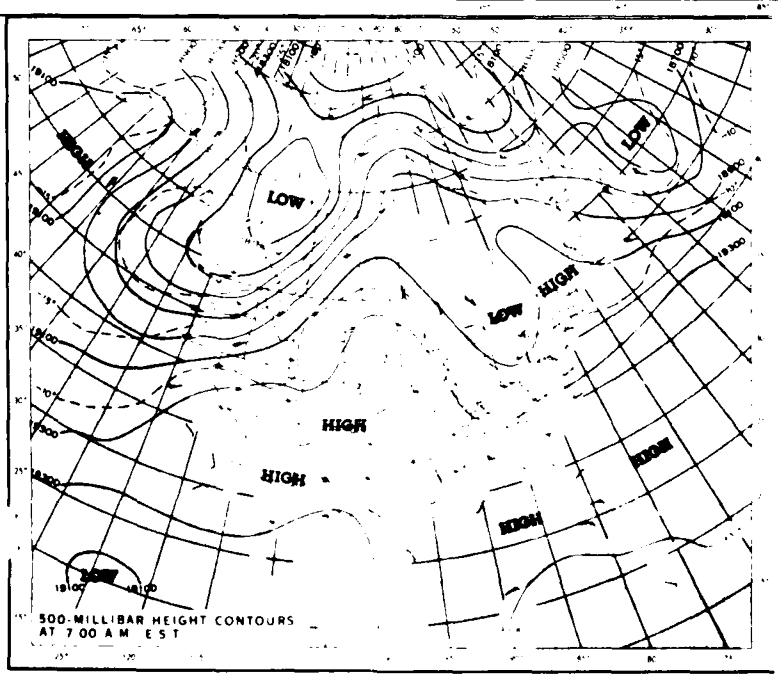
Chief Forecaster

See next page for
Daily Weather Maps 18 Aug 73

Daily Weather Maps 18 Aug 73



SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.



500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.

5.5. Example 5. Persistent Stratus.

This is a good forecast review done by Det 75, 3WS, 5WW at Eglin AFB Florida. It contains most of the necessary information. It could have been improved by attaching copies of the 850mb analyses.

WE 14 Nov 1978

Forecast Review for a forecast issued on 8 Nov 78, vld 1400-2000Z

Memo for File

1. Synoptic situation at 1200Z on the morning of the forecast consisted of a high pressure system located over eastern portion of Texas, and a cold frontal system extending NNE-SSW along the east coast of the US. Winds aloft sfc-050 averaged 350/10.

2. The cold front has passed through the station the previous morning at approximately 1530Z. With frontal passage ceilings had lowered to 1500 feet, but had improved to 12,000 feet by just 3 hours after frontal passage. They remained above 12,000 feet throughout the remainder of the day until going back to 1,500 feet at approximately 0630Z that evening. They remained in that area until the forecast was issued at 1400Z. The forecast called for ceiling to remain at 1,500 feet until 1900Z at which time I forecast ceilings to be above 3,000 feet. This did not occur and they remained below 3,000 feet through the entire forecast period.

3. Sfc obs at Hurlburt were as follows:

TIME	CIG	VIS
1155	M17 BKN	7
1255	M17 BKN	7
1355	M18 BKN	7
1455	M17 OVC	7
1557	M19 OVC	7
1657	E20 OVC	7
1755	E20 OVC	7
1855	E20 OVC	7
1955	E20 OVC	7

4. Recommendations: None.

5. Conclusions: This situation, identified in the TFRN as "post frontal stratus" is a common occurrence in our area. Although the actual stratus layer was only about 1,500 feet thick (based on pireps and the skew-T) it should not have been forecast breakup until the 850mb thermal trough had cleared our station. Close examination of the 1200Z upper air data showed that the thermal trough was still to our west through central Mississippi. Closer attention to the TFRN and upper air data may have prevented giving undue attention to forecast tools such as the conditional climatology tables, fog and stratus checklist breakup times, and surface charts and lead me to forecast no change during this period.

5.6. Example 6. Non-occurrence of Low Ceilings.

This forecast review was done at Det 1, 11WS, 3WW at Elmendorf AFB, Alaska. It provided a good discussion of the forecast reasoning and showed that forecast low clouds occurred throughout the region. This appears to be an example of a "justified" forecast. In cases when forecast timing or location are missed by small amounts, a written forecast review should not be required unless the particular event has been selected as a unit goal for improvement. When this is the case, care must be taken to make sure the pertinent data, charts, and analyses are attached.

Reasoning for Forecasting Ceilings Blo 030, Rain, and Gusty Surface Winds at Elmendorf.

1. Frontal system vicinity Kodiak advancing towards Elmendorf with passage progged about 15Z. Overrunning weather associated with front progged to advect over Elmendorf about 08Z.

2. 700mb moisture prog advecting increased moisture over Elmendorf. 70% line progged by 05/00Z and 90% line progged by 05/06Z.

3. Alaska LFM prog and barotropic showing moderate to strong positive vorticity advection til 05/12Z then becomming neutral to weak negative vorticity advection.

4. Upper air flow 160-200 above 2000 feet, which indicated significant moisture for low ceilings to be advected up Cook inlet over Elmendorf.

POST ANALYSIS

Precip - rain occurred as forecast, including timing.

Wind - timing was as forecast for both direction and speed.

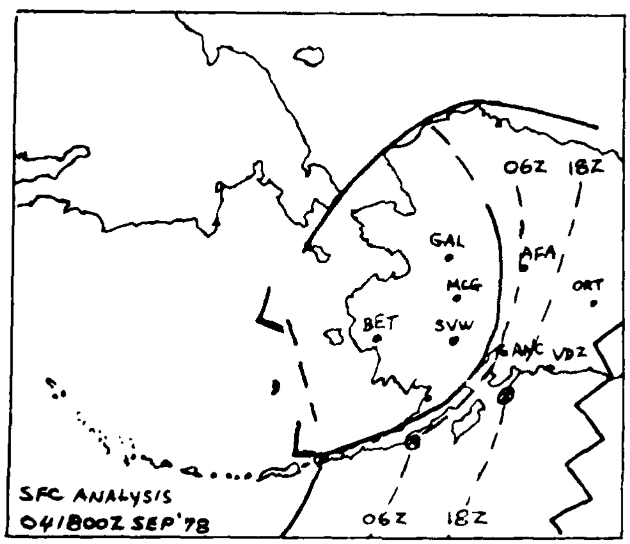
Ceilings - although Elmendorf did not experience ceilings below 3,000 feet, all stations in the area had Cats 3 and 2 ceilings during period. These included:

Anchorage - 3 to 800 feet from 10-18Z.

Anchorage/Merrill - 12 to 2400 feet from 11-16Z.

Homer - 12 to 1800 feet from 6-14Z.

Kenai - 14 to 2200 feet from 7-16Z.



5.7. Example 7. Review of Warning Using AWS Form 39

This is a review of insufficient leadtime in warning of freezing temperatures in Florida. It was done by Det 32, 3WS, 5WW at MacDill AFB, Florida. It illustrates one use of the AWS Form 39. This forecast review could have been improved by examining continuity of the low level (surface to 850mb temperature, moisture, and wind fields.

PERTINENT OBSERVATIONS

MCF OBS 03 Jan 79

0155Z	M 32 BKN 60 BKN 7	45/35	3319	G28
0255Z	E 32 BKN 7	45/34	3320	G27
0355Z	M 32 BKN 7	45/31	3412	G23
0455Z	32 SCT 7	42/30	3513	G19
0556Z	30 SCT 7	40/28	3607	G19
0655Z	30 SCT 7	37/24	0109	
0755Z	CLR 7	33/18	3607	
0856	CLR 7	31/16	0107	
0955	250 - SCT 7	31/13	0107	G16
1055	250 - SCT 7	30/16	0207	G15

(32^{o}F at 0830Z)

Lead: 0830
-0755
00:35

Timing Error: 0900
-0830
00:30

Recommendation: This be maintained as a case file for forecaster information.

BUST REVIEW AND COMMENTS

At our 02/2000Z Map Discussion Briefing, we forecast a morning min temp of 36^{o}F. We recognized very strong cold air advection (see 850mbs). However, we eliminated $<33^{o}$F based on:

1. Strong surface winds from WNW (see 2nd standard level chart)
2. LFM BLW forecast of 25 kts.
3. Ceiling 30 BKN to OVC northwest nearly to New Orleans.
4. Computer forecast 35^{o}F.

The surface observation demonstrate why we busted: cloud cover loss, wind speed slackened, and wind direction shifted from 330^{o} to 010^{o} (right down the Interbay Peninsula).

5.8. Example 8. Review of a Correct Forecast.

This review describes the actions, taken by a forecaster, that contributed to an outstanding forecast. It clearly identifies the important forecasting rules and procedures. The benefits of careful metwatch, complemented with frequent analyses of the upstream area, are clearly illustrated.

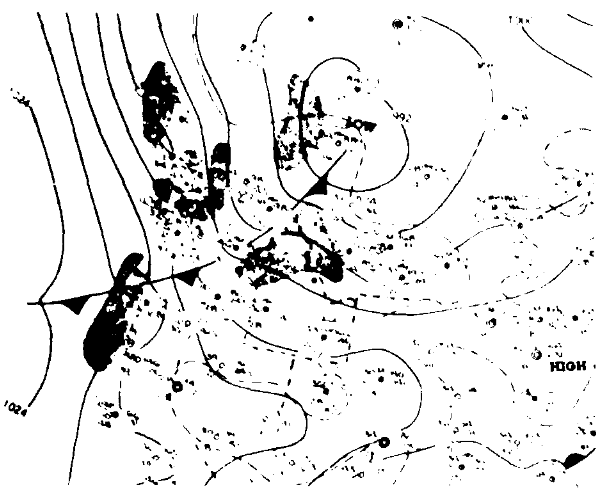
This forecast was made by SSgt Hardamon, Det 18, 25WS, 5WW at Mountain Home AFB. The general synoptic situation is illustrated by surface and 500mb segments from the "Daily Weather Maps" published by NOAA's Environmental Data Service.

Study of Record Equalling Frontal Passage

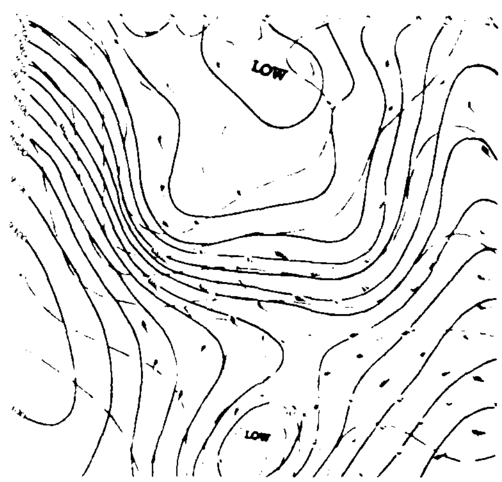
One of the difficult forecasting problems at Mountain Home AFB is forecasting strong surface winds with a cold front passage. A cold front passed through the Mountain Home area at 27/1948Z March 1977. The winds associated with this front peaked at 62 knots which equalled the record for March. The forecaster was able to perform a constant metwatch of the front as it approached through Oregon and successfully forecast the accompanying winds (forecast 55 kts versus actual winds of 62 kts) with over two hours leadtime. Due to the leadtime, damage to the base was limited to mainly fences blown over and very minor aircraft damage. Following is a narrative of events preceding the front passage.

The first map analyzed for the day was the 1500Z surface chart which revealed a cold front through central Oregon with a tightening pressure gradient. The upper air charts showed strong cold air advection into the rear of the front. Although no station was reporting strong gusts on the 1500Z map it was decided that due to the strong temperature gradient aloft and moderate pressure rises on the coast of Oregon, a warning should be issued for 45 kts with frontal passage. As the front passed Baker (BKE) and Burns (4BW) Oregon it was accompanied by winds in excess of 40 knots. At this time the warning was upgraded to 55 kts due to the channelling effect that occurs in the Mountain Home area of the Snake River Plains. The front passed Mountain Home at 1948Z with gusts to 33 kts, 2021Z 55 kts, and at 2029Z we recorded 62 kts. Gusts to 35 kts or greater continued until 0103Z.

Important points to consider with a northeast - southwest oriented front approaching Mountain Home. For early detection of a front that will produce strong winds with passage at Mountain Home look for moderate to strong pressure rises on the Oregon coast (i.e. >3.5 mbs in three hours) accompanied by strong temperature gradients at all levels but at least through the 700mb level. As the front passes Baker and Burns, Oregon add at least 20% to the speed of the peak wind at the stronger of the two stations. A northeast - southwest oriented front will always produce wind directions behind the front of 310° - 330° at Mountain Home due to orientation of the valley. Be aware of what changes are occurring behind the front at all times.



Surface



500mb

Sunday, March 27, 1977 1200Z

5.9. Example 9. Station Chief's Evaluation.

This is a review of unforecast stratus. The reviewing forecaster was not successful in finding the main key needed to prevent recurrence of the missed forecast. The key was provided by the station chief in his evaluation of the forecast review.

The unit that provided this review was Det 16, 9WS, 3WW at Dyess AFB, Texas. The general synoptic situation is illustrated by the surface and 500mb segments from the "Daily Weather Maps" published by NOAA's Environmental Data Service.

UNFORECAST STRATUS

Situation: 9 Mar 1978

The 8 Mar 78 forecast was for existing scattered middle clouds and stratus/stratocumulus to remain east of Dyess AFB. At 0800L the stratus and stratocumulus ceilings advected into Dyess and remained until late in the afternoon.

Forecaster's thinking and support:

The key to the situation seemed to be the 850mb analysis. With the available data at 08/04L, forecast conditions and trend showed stratus to the east. This forecast was based on the 850mb analysis. The analysis at 07/12Z indicated a low in south central Oklahoma with an associated trough from Oklahoma City-Mineral Wells-Del Rio, moving eastward. An 850mb isotherm trough reached into the Texas panhandle. By 08/00Z there was a cold pocket in central Kansas-central Nebraska and another to the east of Dyess. The low had moved into north central Arkansas with the trough lying from Little Rock-Texarkana-Galveston. Based on these parameters, plus NW surface winds, Dyess should have continued to dry out, with cold air advection to its east, and with stratus occurring in the cold air advection.

Actual:

Using hindsight and the 850mb at 08/12Z, there was shown an additional development of a cold pocket in the Texas panhandle. The low had continued to move eastward to Blytheville and trough from Little Rock-Lake Charles. Therefore cold air advection into Dyess from the cold pocket in the Texas panhandle was the cause for the stratus to be advected into us, even though there was a NW drying wind.

Problem solving:

The best way to eliminate this problem is closer analysis of upper air advection and temperatures in the lower 5000 feet. This may have been prevented by an additional upper air sounding at Amarillo for 08/00Z.

UNFORECAST STRATUS REVIEW

9 March 1978

One tool that could have been used at forecast time: 850mb 24-hour Prog. Upon reanalysis of the 850mb prog vt 08/12Z, the isotherm trough was west of Dyess and dictated stratus ceilings for us. Suggest the use of this prog routinely.

Timing for the stratus: 5 degree spread or less as a good guess. Stratus occurred at 4° spread.

No further analysis required.

Signed, Station Chief

Chapter 6

EXAMPLES OF CASE STUDIES

The case studies in this chapter were selected from case studies submitted by the wings and from wing publications. They are printed here to provide a few examples a forecaster can refer to when ideas are needed about format or content. We made some modifications to the case studies, but we retained as much of the original work as possible.

6.1. Example 1. Synoptic Study for Germany.

This case study was taken from the December 1978 2WW Technical Bulletin. It illustrates use of selected portions of operational analyses, and a thorough consideration of all relevant material including previous studies.

A CASE OF SNOW, FREEZING PRECIPITATION, AND RAIN IN WEST CENTRAL GERMANY

Editor's Note: This article by Capt Arthur J. Carrizales, formerly of Det 21, 2WW, the European Forecast Unit, was originally published in the October 1973 issue of the 2WW Technical Bulletin. It is reprinted here as an excellent example of a potentially hazardous weather situation (freezing precipitation) with the associated forecasting difficulties.

On 26 January 1973 the USAFE air bases in west central Germany were affected by a series of frontal systems which produced snow, freezing precipitation, rain and mixed rain and snow over a period of 12 to 18 hours. Many decisions of operational importance may have depended on the forecasts during this time and it is considered useful to post analyze the situation. The purpose of this paper is to review the synoptic picture focusing primarily on use of 26/12Z data to forecast the various types of precipitation. It is hoped that this paper will help forecasters to better handle similar future situations in a timely and effective manner.

During the period preceding the intrusion of frontal systems, an upper level ridge had established itself over Europe. The 25/00Z 500mb analysis (Figure 1) showed the ridge extending from Spain through Germany into western Russia with a high center in the Bay of Biscay. Cold advection on the western side of the ridge was slowly breaking it down. Dry, northeasterly flow prevailed over Germany at this time. The 26/00Z 500mb analysis (Figure 2) indicated that the flow north of 50 degrees latitude was becoming zonal due to the cold advection. The center of the high was now in north central Spain.

While the cold advection aloft was slowly breaking down the ridge over northern Europe, the 25/00Z surface analysis (Figure 3), indicated a ridge extending west to east from the Bay of Biscay to western Russia. A stationary front separating the warmer maritime polar airmass to the west from the colder continental polar airmass to the east was situated north to south from the Benelux countries through central France. A second front was approaching the coast of Ireland, and a third was moving rapidly across the eastern Atlantic under the influence of an upper jet stream. By 26/00Z (Figure 4) the second front was in the London area.

Figure 1. 500mb 25 Jan 73, 00Z

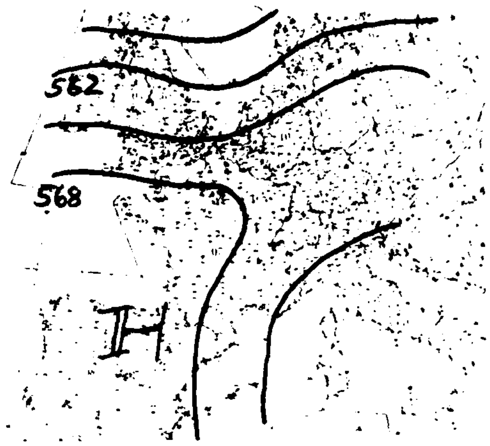


Figure 2. 500mb 26 Jan 73, 00Z

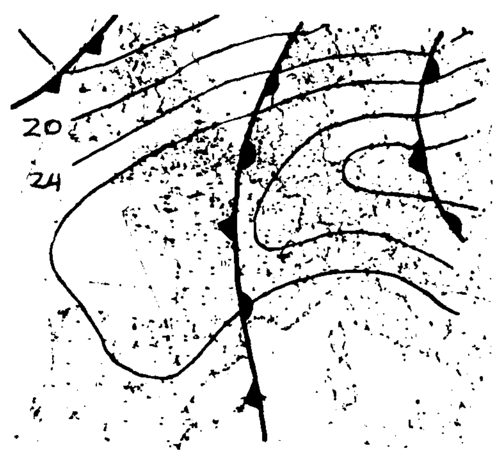


Figure 3. 25 Jan 73, 00Z Sfc.

The third front moved at speeds from 30 to 40 knots after 26/00Z and by 26/12Z had moved into the Irish Sea. By that time the second front had moved onto the continent where it aligned itself from the Benelux countries through western France (Figure 5). In the meantime, the front dividing the warmer maritime air from the colder continental air had moved eastward to a position just west of the USAF air bases in Germany.

An analysis of the lower troposphere from Belgium across central Germany at 26/00Z showed that the dome of cold air was shallowest at the westernmost station, St. Hubert in Belgium (06476), and thickest at the easternmost station, Gammersdorf (10771). See Figures 7, 8, and 9.

By 26/12Z it was apparent that the inversion had weakened at St. Hubert due to slight cold advection in the lower levels. It was also noticeable that the cold air was affecting Idar-Oberstein (10618) at 26/12Z (Figure 8). This cold advection at the surface was most apparent at Hahn Air Base, 12 miles north-northwest of Idar-Oberstein. At 26/04Z Hahn reported 0600 meters visibility in freezing fog with a 100 foot ceiling. By 26/13Z visibility improved to 9000 meters in haze, and the ceiling rose to 2000 feet.

It was now becoming evident that the cold front approaching the stationary front (Figure 5) would go aloft since the air behind it was less dense than the colder airmass over the continent. This conclusion was reached by analyzing the Idar-Oberstein sounding, which showed that the low level inversion had not weakened significantly, even with slight cold advection in the lower levels. This sounding also indicated an increase in moisture from the 950mb level to the 500mb level. The problem now facing the forecaster in Germany was not only to forecast the onset of precipitation but, more importantly, the kind of precipitation. Some factors considered in making this forecast were the freezing level, the surface temperature, the 850mb temperature, and the thickness forecasts.

The freezing level is the parameter which determines whether or not snow can reach the ground. The freezing level in west central Germany on 26 January was on the surface (Figure 10) with a few Air Force bases reaching a high temperature of 1C during the day. Observational evidence has previously shown that a freezing level averaging 1200 feet or more above the ground is usually needed to insure that most of the snow will melt before reaching the ground. Since the height of the freezing level is difficult to forecast accurately it has limited

Figure 4. 26 Jan 73, 00Z, Sfc.

Figure 5. Sfc. 26/12Z Jan 73

Figure 6. Sfc. 27/00Z Jan 73

value as a predictor of rain versus snow. Instead, the surface temperature is generally used but in conjunction with upper level thermal considerations.

Previous studies show that the 850mb temperature is a good forecasting discriminator between rain and snow conditions. In Europe, observations have indicated that snow should be forecast with temperatures of -4C or lower. This is not to say that snow does not occur at temperatures higher than -4C but that in the majority of cases when it does occur the 850mb temperature is -4C or colder.

A fourth parameter considered was the forecast thickness. Data have shown that freezing precipitation should be forecast when the 1000mb to 850mb thickness is in the range 1280 to 1320 meters and when the following criteria are met:

1. The surface temperature is less than or equal to -2C.

2. The warmest temperature in the sounding is equal to or greater than -2C.

3. The 850mb temperature is or is forecast to be -4C or warmer.

4. The synoptic situation agrees with one of the Miller types (in this case, the corresponding Miller type states that the polar track is established south of 50 degrees north with rapidly occluding waves moving into western Europe from the west).

With all this information available it might seem that the forecast would not be too difficult to make. The following were established:

1. The cold continental airmass was more dense than the warmer maritime airmass approaching from the west behind the "cold" front. This suggests that the cold front would go aloft.

2. The 850mb temperature was between 9 and -4C (Figure 9) with warm advection which would indicate that the precipitation could start out as snow, but its duration would be short.

3. The freezing precipitation work chart used by Det 21, 2WW indicated a definite potential across central Germany but since it is an intermediate phenomenon between snow and rain, its duration would be short.

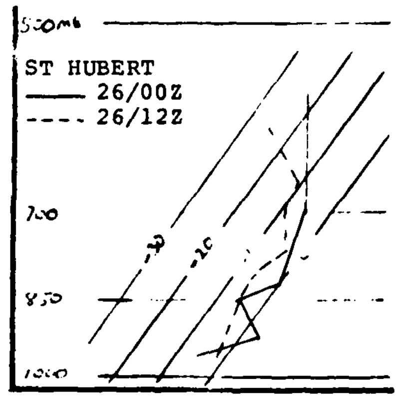


Figure 7. St Hubert sounding 26 Jan 73

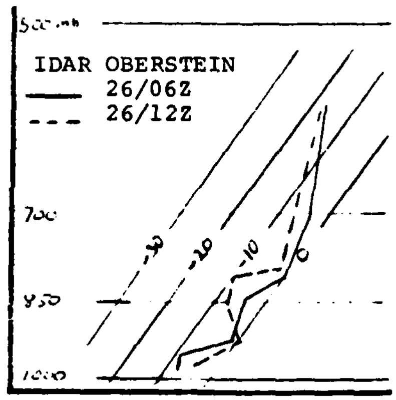


Figure 8. Idar Oberstein sounding 26 Jan 73

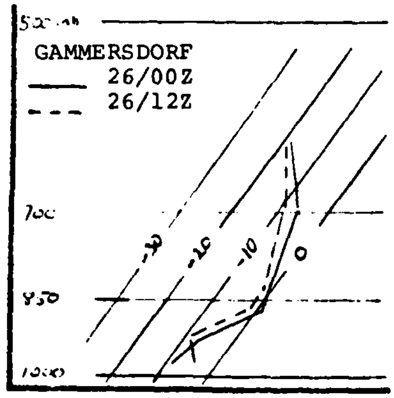


Figure 9. Gammersdorf soundings 27 Jan 73

4. As west central Germany became more influenced by the maritime airmass, precipitation would change to rain. The logical inference from this data was that precipitation would probably start as snow, quickly change to freezing precipitation, and shortly thereafter turn to rain. This did not occur!!!

A typical example of what did happen was recorded at Zweibrucken AB in the following observations:

26/17Z	71SN
26/22Z	61RA
26/23Z	56FZDZ
27/00Z	61RA
27/01Z	77SN
27/02Z	68RASN
27/06Z	68RASN
27/08Z	61RA

Why did the precipitation follow this unusual pattern? What actually occurred in the lower atmosphere? The 26/12Z 850mb chart (Figure 10). indicated warm advection over western Europe. This was the dominant factor in the forecast. The warm advection at the 850mb level along with vertical uplifting caused by the front was expected to change the snow to rain. Apparently the warm advection was weak and was neutralized by the cold dome over central Europe. This was indicated in the lower levels by the surface temperatures. There was little warming on the surface. This should have provided a clue to the weakness of the warm advection in the lower levels. Another parameter that should have been considered was evaporational cooling that usually occurs in low levels when the wet-bulb temperature is close to or below freezing. A third factor we should have considered was the effect of overrunning from the third frontal system. The cold advection from this system was also affecting western Germany by 27/00Z.

Figure 10. 850mb temperature analysis 26/12Z Jan 1973

Conclusion.

With so many parameters to consider a forecaster must select and focus on those which are important, then carefully analyze those features necessary to make a viable forecast. Hopefully this study will provide insight into the selection and analysis of critical parameters in forecasting "rain versus snow" situations and will thus aid future forecasters to make timely and accurate forecasts.

6.2. Example 2. Ice Storm.

This study is similar to Example 1. It illustrates a different format. It was prepared by Det 2, 3WS, 5WW at Seymour Johnson AFB, NC.

ICE STORM OF THE 8th AND 9th OF JANUARY 1971

SEYMOUR JOHNSON AFB, N. C.

The major problem facing the duty forecasters on the 7th and 8th of Jan was what type of precipitation will occur - rain, snow or freezing rain.

If rain or snow were to occur, the amounts would not be excessive and would present little problem.

But freezing rain or any amount over .25 inch would present a serious problem and could cause extremely hazardrous conditions. The resulting accumulation of ice on parked aircraft, ramps, taxiways and runways could seriously impair the operational capabilities of the flying units. In addition, ice on streets and highways presents a serious safety hazard. Ice on trees, utility lines and buildings causes damage and becomes a threat to the health and comfort of personnel.

Large scale synoptic features prior to the onset of the ice storm:

2 Jan - First evidence of a major upper trough at 500mbs in the western United States. High index existed from the Rockies to the East Coast. Weak front extended from Great Lakes region to West Texas.

3 Jan - 500mb trough intensified rapidly over the Rockies but East Coast remained under high index. Front in the Mid-United States became better defined with rapidly deepening low in NE Oklahoma. Weak surface high pressure ridge over East Coast.

4 Jan - 500mb trough now dominates western 2/3 of United States. 992mb low moves from Oklahoma to central Wisconsin. Front extends from Wisconsin. Low to the New Orleans area. SW flow up to 500mb over East Coast. Weak ridge of surface high extends from NE down over the Carolinas.

5 Jan - 500mb trough now dominates most of the United States. SW flow at 500mb extends from Texas to New England. Cold front passes GSB. High pressure moves from Canada to central United States and is building rapidly.

6 Jan - 500mb trough shows little change. Upper flow now very strong and is oriented SW to NE from Texas to New England. Width of the band is from the upper trough axis over southern Minnesota to Florida. Surface high is now at 1036 mb central pressure and located over eastern Kansas. Front extends from central Gulf of Mexico to central Florida then NE into the Atlantic.

7 Jan - 500mb trough extends from Great Lakes region to the SW into Arizona. Broad band of strong SW to NE flow continues over eastern United States. First evidence of low development in central Gulf of Mexico. Arctic high now over southern Illinois and moving slowly east.

8 Jan - 500mb trough shows evidence of filling and moving slowly to the east. Surface high now in southern Pennsylvania. Weak "cold finger" extends down over Virginia and the Carolinas. The wave on the front is now well defined in the Gulf of Mexico and moving NE. Very light ice pellets were observed at GSB at 0500E and 0600E. At 0740E a mixture of light rain and light ice pellets was observed. At 1227E very light snow and ice pellets were observed. The surface temperature has remained at around 35°F during this period. At 1447E a mixture of light rain and light freezing rain was observed and the temperature had dropped to 31°F. At 1745E the light rain was dropped and only freezing rain was carried - this continued until 09/0800E and the surface temperature remained 32°F during this 14 hour period.

9 Jan - Cut-off low at 500mb over Baja, California. The 500mb trough over central United States is weaker and SW flow over eastern United States is still present but is now weaker. Surface low has moved across Florida and is now about 200 NM east of ILM and moving ENE. Surface high over New England with weak "cold finger" moving

slowly out of the South Atlantic States. Low ceilings and restricted visibility continued throughout the day, but the temperature remained at 34°F and no further accumulation of freezing precipitation occurred.

CLUES TO THE ICE STORM THREAT

1. Location of the cold high pressure system.

a. Center of the high located to the north (Ill, Ind, Ohio, Pa.). Moving east or east by northeast very slowly.

b. Tongue of cold air extends down the Atlantic Seaboard - a form of the "cold finger".

2. Surface front will be to the south and/or southeast and will be quasi-stationary.

a. Wave will form on the front in Southern States (La, Miss, Ala, Ga) or in the Gulf of Mexico.

b. Wave will develop into a closed low and move rapidly to the east-northeast passing into the Atlantic Ocean after crossing the Florida, Georgia or South Carolina coast.

c. Low may slow down and deepen off the North Carolina coast - most serious threat.

d. Low may continue to E or ENE into the Atlantic Ocean and shorten the duration of the threat to the GSB area.

3. Upper air flow will be from the SW at least up to the 500mb level and be strong and in a broadband covering most of the east coast of the United States.

4. Surface to 3000 ft winds have a NE direction as a result of the pressure ridge extending from the high cell to the north. The cold flow from the north has a short over water trajectory and has been slightly modified. Surface temperatures are in the low thirties - usually between 30°F and 34°F. Thus, light or very light rain or drizzle falling into this cold layer will freeze on contact. When this condition persists for several hours a heavy layer of ice will accrue.

5. If the surface low slows down and deepens off the North Carolina coast and the low level winds increase to 15 knots or more the potential for extensive damage to power lines and trees is very great.

SUGGESTED ACTIONS WHEN THE ICE STORM THREAT IS PRESENT.

1. LAWC's every three hours, more frequently if workload permits and manpower is available.

2. Plot GSO, CHS and AHN soundings:

a. Check layer thickness.

b. Look for inversions.

c. Look for warm layers.

3. Keep continuous metwatch:

a. Look for bright band(s) on the FPS-77.

b. Look for possible convective activity - TSW has been carried at GSB when the low on the front moved close to our area.

4. Keep snow vs rain worksheet and check the probability of occurrence of snow/rain.

5. If the low moves NNE and the front does not move well out of our area, be alert for a second open wave or low development that might cause the freezing rain to start again.

6. Collect and retain all pertinent data, charts and radar photos that might serve to improve this case study.

SNOW VS RAIN WORKSHEET - GSO SOUNDINGS FOR 8 AND 9 JANUARY 1971

LAYER	08/00Z Z_T	DEPT	TYPE	%	09/00Z Z_T	DEPT	TYPE	%	09/12Z Z_T	DEPT	TYPE	%
1000-850 EPT 1310m	1285	-25	Snow	70%	1283	-23	Snow	65%	1300	-10	Snow	59%
1000-700 EPT 2787m	2821	+34	Rain	75%	2847	+60	Rain	83%	2843	+54	Rain	80%
1000-500 EPT 5333m	5339	+6	Rain	55%	5306	-27	Snow	72%	5408	+85	Rain	88%
850-700	1536	+3	Rain	51%	1564	+31	Rain	83%	1543	+10	Rain	60%

EPT = Equal probability thickness at which there is an equal probability of rain or snow occurring. DEPT is departure from EPT.

Z_T = Thickness of the layer

% == The % probability of the precipitation being of the type indicated

GSO Sounding for 08/12Z was not available.

The 08/00Z sounding shows good indications of snow for the 1000-850 layer (the cold finger ridge). The 1000-700 layer shows strong indications of rain (warm layer from 860 to 742 accounts for this). The 1000-500 layer indicates a very slight edge to rain (55%).

By 09/00Z two layers (1000-850) and (1000-500) showed strong indications for snow but the other two (1000-700) and (850-700) showed even stronger indications for rain.

By 09/12Z the only layer showing indications of snow was the 1000-850 and this by a 59% probability. Rain was strongly indicated by all other other layers.

6.3. Example 3. Strong Wind.

This study illustrates a thorough analysis. The introductory paragraph is especially good because it states the problem, and outlines the following sections. Furthermore, the following sections do what was advertised in the introduction. This study was done by Det 11, 9WS, 3WW at Beale AFB CA.

Case Study for 7 Feb 1978 Mar 16 1978

Files

1. This is a case study of strong wind occurrences at Beale AFB, associated with a vigorous frontal system, which moved across northern California on 7 February, 1978. This discussion will cover the general synoptic situation, a synopsis of events at Beale and the forecast reasoning which was used to analyse the situation. I will include a post analysis to critique the methods used and apply other analysis techniques. Finally I will summarize and conclude with suggestions for analysis and forecasting of surface wind patterns with such storms.

2. General Synoptic Situation:

a. Upper Air: A broad, deep trough had been entrenched over the Eastern Pacific for several days. Just west of the California coast the flow turned from southwesterly to zonal. The jet was over the Beale area, with speeds of 160 knots at 250mb on the Oakland sounding at 1200Z. Superimposed upon the long wave trough were a series of short waves, supporting surface frontal systems. These short waves were moving eastward, through the long wave trough at 90 to 100 knots. At 12Z on the 7th, a short wave was located along the axis of the long wave trough, distorting it only in amplitude. By 00Z the short wave had moved inland while the next one was moving into the back side of the long wave trough, distorting it into a box like pattern. The flow pattern was difluent over northern California. The long wave pattern deepened with height and had positive tilt. It was of moderate depth with a 500mb contour height of 5540 meters over the Beale area.

b. Surface: A series of frontal systems were moving eastward across the Pacific in phase with the short wave aloft. These fronts were observed from the GOES West satellite pictures to be moving at speeds approaching 100 knots. At 1200Z on the 7th, there was a front just west of the California coast, anchored on a low just off the Washington coast. The triple point was analysed at 39°N at 1200Z and again at 1500Z by NMC. By 1800Z the frontal system had moved onshore, and the availability of data made it apparent that there was no warm front. This appears to be a fairly typical pattern for NMC analyses along the west coast. (Hand drawn copies of the NMC surface analyses are included as attachments 1-3 to this study. No attempt was made to reanalyse the surface data, since the purpose of this study is to provide for forecasting future similar situations) The precipitation pattern extended 200-400 miles ahead of the frontal system. The isobar pattern was oriented zonally over northern California. At 0500Z there was a 4mb gradient from Sacramento to Red Bluff. It was the same at 1200Z, but by 1800Z it had dropped to 3.5mb. At this same time the Fresno to Red Bluff gradient was 11.9mb. In the past, however, we have not found a good correlation between high winds at Beale and a strong Fresno to Red Bluff gradient. (It should be noted that the rugged topography of the region causes the frictional terms of the equation of motion to be much stronger than the coriolis terms so that we usually have direct cross-isobaric flow in the central valley).

3. Synopsis of events at Beale: On the previous two days, fronts associated with short wave troughs had passed through the Beale area with rain and strong winds. Weather Warnings for winds greater than 35 knots had verified both days. A frontal passage had occurred at 2240Z on the 6th. The rains had ceased by 0240Z, but the ceiling remained between 4000 and 6000 ft through most of the night. By 1000Z the ceiling had dropped to 3000 ft. Rain began at 1225Z and the winds began gusting over 25 knots from the southeast by 1400Z. The rain increased to moderate intensity at 1620Z. The first gust to 35 knots occurred at 1639Z. At 1731Z there was a gust to 51 knots. At this same time thunder was heard in the base housing area. Gusts to 40-45 knots continued to 2040Z; a rapid pressure rise began at 2031Z. The winds shifted southwesterly and died off at 2100Z, indicating frontal passage. Intermittent light rain showers continued until 2230Z, when clearing began and the winds subsided below 10 knots.

4. Forecast Reasoning: The frontal system approaching the coast was identified as satellite pictures. The system was moving so fast that the numerical progs, could not handle it. However, the situation was quite similar to that of the two previous days. On the 5th there were several gusts to 40 knots, while on the 6th there was only one gust to 35. On the 0500Z RTAF worksheet for the 7th, the approaching system was stated that winds of 34-40 were to be expected prior to frontal passage. A weather warning was issued at 1600Z for gusts to 35 knots. At 1710, as the winds gusted past 40 knots, the warning was amended to 45 knots. An after-the-fact warning was issued at 1730, for winds gusting past 50 knots.

5. Post Analysis:

a. Standard analysis techniques had identified the strength of the nonconvective winds in this system 15 hours before they occurred. There was, however, a hesitancy to forecast winds above 35 knots until the issue time of the weather warnings. There was also a tendency to wait until another station in the valley carried 35 knot winds before issuing the weather warning. The 51 knot gust was most likely due to downrush gusts from the thunderstorm, heard in the base housing area. This storm was not detected on the 1730Z SAC RAREP. Precipitation attenuation may partially account for this. Maximum reported tops over the Beale Area at that time were 11,000 ft.

b. AWS TR 200 (REV) May 1972, Chapter 10 discusses methods of forecasting maximum gusts from thunderstorm cells. The method discussed in Section B, para b was applied to the 1200Z OAK sounding, which predicted a maximum gust of 3 knots. The techniques discussed in this chapter have little benefit for Beale for several reasons. Thunderstorms at Beale are nearly exclusively associated with frontal systems. The thunderstorms themselves are seldom severe. The strong winds are usually associated with the synoptic scale pressure field, the gust fronts from the thunderstorms are usually in the 10-15 knot range. The methods described in Chapter 10 predict the gusts for the peak intensity of the life cycle of a storm. This is of limited value in forecasting peak gusts at an arbitrary point, like an aerodrome, unless you are certain that the storm will be at peak intensity when it passes that point. The ability to make such forecasts at a base without a radar is certainly not within the current state-of-the-art. Another problem is that there is no upper air station in the Central California Valley. Given the large role of the topography in initiating convection, the applicability of instability data from the Oakland sounding, to conditions at Beale is highly suspect. Therefore, the use of the techniques described in this chapter would probably not provide as high a verification as merely adding 5-10 knots to gust speeds when thunderstorms are expected with the already strong surface winds.

6. Conclusions. With vigorous, fast moving winter frontal systems, where a jet of 100 knots or greater is over northern California, winds between 35 and 49 knots should be expected 6 hours prior to frontal passage, in the Sacramento Valley. They will not always be experienced at Beale AFB, although they will occur here in the majority of cases. If there is sufficient instability for heavy rain or thundershowers, 5 to 10 knots should be added to the peak surface gusts. Weather Warning for these winds should be issued based upon the synoptic situation. Waiting until the winds exceed 35 knots in the Sacramento area or until they approach 35 knots at Beale will not provide the desired leadtime of 1 hour. This will result in the issuance of warnings which do not verify. However, weather warning coverage and timeliness are more important than a high rate of verification. To insure that the continuity of reasoning is maintained, prior to each forecast, the previous 24 hours of forecast worksheets should be read and the forecast reasonings considered. The low level wind forecasts included in Model Output Statistics bulletins should also be closely watched in considering strong winds in the 12 - 36 hour period downstream.

Chief Forecaster

3 Atch*
1. SFC Anl 1200Z
2. SFC Anl 1500Z
3. SFC Anl 1800Z

* Attachments withdrawn.

6.4. Example 4. Low Level Jet.

This is an example of a case study with a very limited purpose - it shows that a low level jet can develop within six hours. The study was done by CMSgt Eugene Weber and published in the March 1978 3WW Metwatch.

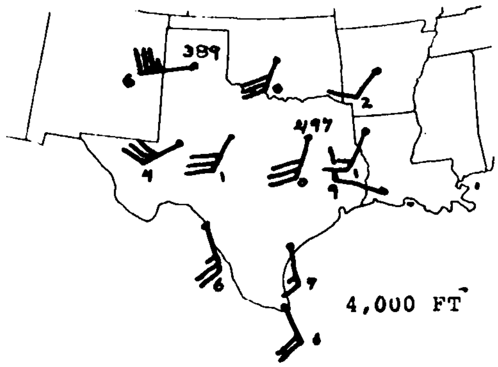


Figure 1: 00Z 6 March 1964

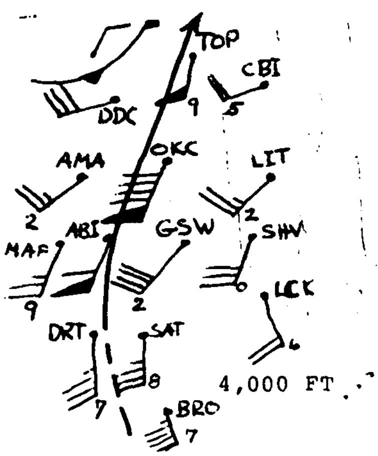


Figure 2: 06Z 6 March 1964

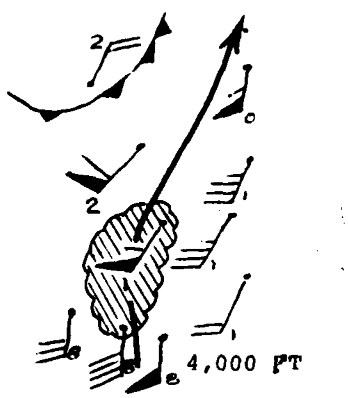


Figure 3: 12Z 6 March 1964

An example of strong low level jet development over the central and southern Plains is shown and serves as a reminder that the windy months of early spring are here. Figures 1-3 depicts jet development over six hour periods beginning at 0000Z. Reported maximum winds over Oklahoma City (OKC) were in excess of 85 knots above 2,000 feet.

Low level jet development over the Midwest occurs often between 0600Z and 1200Z. Unfortunately, wind reports are no longer taken at 0600Z and 1800Z, thus the detection of strong jet activity could go unnoticed between receipt of the 00Z and 12Z wind data. One of the best indicators of nocturnal jet development is surface reports of gusty winds which could pinpoint the jet axis.

Figures 1-3 shows an example of strong jet development during the early morning hours in March. Some of the reporting stations shown in the figures no longer report. Gulf stratus advection (ceiling $\leq$ 5,000 feet) reported along the jet axis (Figure 3) is shown as a scalloped hatched area (the low level jet and Gulf stratus relationship are discussed in 3WW Tech Note 76-1 "Low Level Moisture Advection").

In Figure 1, 30-35 knot wind speeds were common in the area of strongest winds; however, no distinguishable jet was evident.

Six hours later (Figure 2), a strong jet appears over Kansas, Oklahoma and Texas; OKC reported maximum winds of 89 knots at 4,000 feet (see Table 1). The table shows 1,000 foot increment winds to 6,000 feet at some stations near the jet axis.

In Figure 3, the jet has shifted eastward and developed southward into southern Texas. Gulf stratus appeared five hours earlier (07Z) in the San Antonio (SAT) area and has advected into northern Texas.

In summary, low level jets can develop rapidly within a six hour period preferably during the late night - early morning period. These jets are often strong during the early spring season. Met watch of surface wind reports across the Plains states could flag formation.

STATION	WINDS ALOFT					
	1,000	2,000	3,000	4,000	5,000	6,000
TOP	-	1742	1849	1951	2049	2242
OKC	-	2048	2085	2189	2188	2283
ABI	-	1722	1947	2055	2153	2251
GSW	1830	1944	2043	2241	2339	2434
BRO	1533	1543	1545	1743	1844	-

Table 1: 06Z 6 March 1964

6.5. Example 5. Snowstorm.

This study was done by Det 5, 5WS, 5WW at Fort Knox, KY. The record snowfall was correctly forecast primarily using centrally prepared facsimile and teletype products. Copies of NOAA Daily Weather Maps and selected teletype bulletins (MOS, LFM Output, and trajectory) were attached to the original.

29 September 1978 5WS, Det 5 TFRN (C8)

CASE STUDY

of the

16-17 JANUARY 1978, MIDWEST SNOWSTORM
by MSgt John Slaby, Chief Forecaster

1. It seemed like an avalanche fell on the Ohio River Valley on 16 and 17 January 1978. It was the heaviest snowfall ever recorded in this area, nearly two feet had fallen at some nearby locations in just 24 hours. Fort Knox got 11 inches which broke the previous 24-hour January record by 4 inches. The snowstorm resulted from a typical "Texas Wave". This wave was a culmination of a series that had developed that 77-78 winter under a very unusual and persistent long wave pattern.

2. A cut off blocking ridge aloft over the Gulf of Alaska shunted vigorous short waves south of the high on a west-east track from California across the United States. This block anchored a long wave trough over the eastern half of the country that fed arctic air over the Midwest. As the minor waves moved eastward underneath the jet stream along the southern border, they pumped warm moist Gulf air over these cold persistent domes. (See the accompanying NWS Daily Maps - Atch 1.) The short wave that moved inland Sunday morning, January the 15th, produced the snowstorm addressed in this study. There were 70 to 90 knot winds around the trough at 500mbs. It moved from coast to coast in just 72 hours. The surface "Texas Wave" had formed by 0700EST, 16 January. Although it was not an intense appearing cyclone on the surface, the atmospheric dynamics aloft for a storm were more than amply present.

3. Heavy snow had begun at Fort Knox by sunrise on the 16th. The first point warning for 7 inches, which had been issued before any accumulation occurred, was upgraded to a foot of snow at 1200EST (after only 3 inches had fallen) based on the latest progs and RAOBs. All total, 10.8 inches of new snow was officially recorded at the airfield from the 16th at 0700EST to the 17th at 0700EST. At the NWS Regional Forecast Office in Louisville, KY, 17 inches were recorded.

4. The detachment forecasters did a magnificent job forecasting this storm. Our customers were warned as early as Sunday morning, the 15th, by the standby forecaster that heavy snow was coming the next day. We were consistently ahead of the local NWS weathermen and TV weather casters (who unanimously underestimated the strength of this system) in our predictions of the onset and intensity.

5. But the main purpose of this study is to praise the centralized products that helped us make these accurate predictions. Much of the credit should go to the centralized guidance, it was the first alert of the storm, the guidance element forecasts met the commonly accepted rules for heavy snow, and the timing was excellent. An evaluation of the individual guidance products follows. Forecasters in the future should continue to rely on these products in combination with local analyses. They are, in my opinion, the best tools we have for winter weather forecasting.

a. The Limited Fine Mesh (LFM) facsimile charts based on the 16/0000GMT observed data was nearly a perfect prog.

(1) The forecast 1000-500mb thickness at 16/1200GMT was 5330 feet; the optimum for heavy snow is considered to be 5330 feet.

(2) Heaviest snowfalls usually occur under the thickness ridge; it too was forecast over Kentucky by 17/0000GMT.

(3) The trough amplitude at 500mbs deepened from the 16th to 17th over the local area. This is a very good indicator of strong upward vertical motion.

(4) Optimum track for the vorticity maximum center is 2½ degrees south of your location; the actual track was 3 degrees of latitude.

(5) A strong influx of moisture was exhibited. The RAOBs at 16/1200GMT, received at 1400GMT, and the precipitable water chart verified this prognosis. At 5000 foot over Little Rock the observed winds were 53 knots from the southwest (220 degrees), in other words, the jet was pointed directly at central Kentucky. From the precipitable water analysis at 16/0000GMT, it was evident the moist tongue lay over this low level jet. The maximum moisture content was over Texarkana, AR - 1.17 inches.

(6) The actual track of the surface low center tracked further north than the LFM progged; but since there was no well-developed center, this miss did not affect the forecast. LFM progs did correctly forecast splitting of the surface center. A Local Area Work Chart was analyzed at 16/1800GMT for pressure tendencies to supplement the LFM. It clearly indicated the areas of maximum positive vorticity and the direction of low movement. An inverted isobaric trough was oriented southwest through northeast from Arkansas to southern Indiana; the sharpest pressure falls were in a narrow dogleg line from Little Rock to Memphis to central Kentucky, just south of Fort Knox.

b. FOUS 65 KWBC, which is a LFM-derived, product, forecast:

(1) Very strong vertical velocity upward throughout the period. The maximum was +3.6 microbars/sec (at the 700mb level) valid at 16/1800GMT.

(2) Total precipitation to be .82 inch - water equivalent - in the 24 hours after 16/1200GMT, the start of the storm.

(3) All precipitation to be in the form of snow. This was obtained from the element forecasts for thickness and mean boundary layer temperatures which are plotted on the locally derived precipitation type nomogram. The forecast thermal conditions were in the high range of snow on the nomogram which also indicated the air mass was capable of containing large amounts of moisture. FOUS 65 however missed the changeover to freezing rain that occurred shortly after midnight from 17/0500 to 0900GMT. Temperatures approached but did not cross the boundary into freezing rain from the forecast plots on the nomogram.

(4) Timing was perfect. Large moisture increases began at 16/1200GMT when heavy snow started and significant drying was forecast when it ended.

(5) Almost the same conditions were present on the next forecast bulletin based on the data run valid at 16/1200GMT. The precipitation forecast was even a little higher - .99 inch - hitting the actual snowfall almost exactly.

c. The Model Output Statistics-bulletins - FOUS 7 and YAXX 9 - also were very good forecasts.

(1) Both products forecast a 40 per cent probability of 2 inches or more of precipitation (water equivalent).

(2) A probability of 50 per cent for a heavy snowfall from 17/0000 to 1200GMT. (Unfortunately, we did not receive an "Early Guidance" bulletin in the previous 12 hours.) The categorical snowfall forecast missed; less than 4 inches was forecast.

(3) POPs (probability of any precipitation) averaged 90 to a 100 per cent.

d. GWC's trajectory model backed up the NWS products.

(1) Constant pressure level trajectories at the 500 and 700mb levels indicated extreme upward vertical velocity - as much as a 100mbs - after 16/1200GMT.

(2) Large increases in moisture to total saturation at all levels were progged.

(3) GWC's trajectory picked up the low level warming trend, whereas the NWS models didn't. The 850mb temperature was forecast to rise to 0 degrees Celsius at

17/0600GMT and the 2000 foot temperature to +4 degrees C, indicating a changeover from snow to rain. It was discounted because the 2000 foot temperature forecast was thought to be too warm. Which it was, but the GWC trajectory still gave the best indications of a possible change to freezing rain which, subsequently, occurred.

e. NWS's trajectory model was not as accurate as GWC's this time. FOUS 52 KWBC was much too dry below 700mbs with a spread of 5 Celsius degrees at the 850mb level valid for 17/0000GMT. This was at the height of the storm, and the surface spread was an even greater 12 degrees. On the next run forecast temperatures and dew points were more reasonable. The NWS model had two good forecasts, though.

(1) Extreme positive vertical motion was indicated after 16/1200GMT - 100 millibars in 12 hours at the 700mb level.

(2) The forecast 850mb temperature was forecast to be in the optimum range of -3 to -5 degrees Celsius at -4.5 degrees C.

6. Analyses the next day as the storm was ending also verified two rules. Fort Knox experienced the last heavy snow at 17/1400GMT as the 850mb low center passed. The center was pinpointed from 1200GMT RAOB data. Light snow ended at the same time when our extrapolation showed the 700mb trough should have moved through, at 17/1900GMT. We had to amend one rule based on this storm and others last winter. It had been an accepted rule that the 850mb 0 degree Celsius isotherm does not move northward when the air is saturated due to the cooling effect of the evaporation of precipitation. The 0 degree isotherm is a key determinant of precipitation type. Since at the beginning of the 16 January storm, the 0 degree line was across northern Alabama, Mississippi, and Arkansas, and the air was totally saturated, and we still had a change in type, we had to adjust this guideline. The 850mb 0 degree C isotherm should move at 20 per cent of the 5000 foot wind normal to the isotherm in saturated air.

END

DTIC

6-86